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# RESEARCH MEMORANDUM

TESTS IN THE AMES 40- BY 80-FOOT WIND TUNNEL OF THE EFFECTS  
OF VARIOUS WING MODIFICATIONS ON THE LONGITUDINAL  
CHARACTERISTICS OF TWO TRIANGULAR-WING  
AIRPLANE MODELS WITH AND WITHOUT  
HORIZONTAL TAILS

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## SUMMARY

An investigation was made with the objective of eliminating destabilizing changes of pitching moment through the use of wing modifications for two airplane models having triangular wings of aspect ratios 2 and 3. The models were tested with horizontal tails located above the extended wing chord plane as well as with the tails off. Chord extensions and fences, alone and in combination, were the principal wing modifications considered. The unfavorable stability changes through the lift ranges of the basic models were not entirely eliminated by the modifications tested. However, considerable improvement was obtained for both models with the use of a chord extension in combination with a fence.

## INTRODUCTION

For high-speed airplanes having horizontal tails, it has been found desirable for aerodynamic and structural reasons to place the tail above the extended wing-chord plane. However, for airplanes with low-aspect-ratio wings and with the tail above the wing chord plane, for certain tail lengths, destabilizing changes of pitching moment occur for portions of the lift range. This effect occurred for the two models reported in references 1 and 2, which were equipped with aspect ratio 2 and 3 triangular wings. An investigation was undertaken in the Ames 40- by 80-foot wind tunnel to study the possibility of reducing the destabilizing changes of pitching moment of these models through the use of wing modifications which included chord extensions, fences, and combinations of chord extensions and fences.

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A secondary objective of the investigation was that of improving the longitudinal stability characteristics of the models with the horizontal tail removed.

The complete range of wing modifications tested is shown in figure 1; however, only the results which indicate the general effectiveness of each type of wing modification are presented herein. A limited number of these modifications were used for the investigation with the horizontal tail off.

#### NOTATION

$b$	wing span, ft
$b_f$	flap span (movable), ft
$b_t$	horizontal-tail span, ft
$c$	wing chord, measured parallel to wing center line, ft
$\bar{c}$	mean aerodynamic chord of wing, measured parallel to wing center line, $\frac{\int_0^{b/2} c^2 dy}{\int_0^{b/2} c dy}$ , ft
$C_D$	drag coefficient, $\frac{\text{drag}}{qS}$
$C_L$	lift coefficient, $\frac{\text{lift}}{qS}$
$C_m$	pitching-moment coefficient, $\frac{\text{pitching moment}}{qSc}$
$l_t$	distance from moment center to pivot line of the horizontal tail, ft
$q$	free-stream dynamic pressure, lb/sq ft
$S$	total wing area, sq ft
$S_f$	trailing-edge flap area (total movable), sq ft
$S_t$	total horizontal-tail area, sq ft

x	longitudinal coordinate parallel to the model plane of symmetry, ft
y	lateral coordinate perpendicular to the model plane of symmetry, ft
z	vertical coordinate perpendicular to the wing chord plane, ft
$\alpha$	angle of attack of the wing chord plane with reference to free stream, deg
$\delta_f$	flap deflection with reference to the wing chord plane, deg
$\eta$	$100 \left( \frac{2y}{b} \right)$

#### Configuration Designation

C	midchord portion of fence
$E_{l \rightarrow m}$	chord extension with chord extended $0.15c$ and with inboard end at $\eta = l$ and with outboard end at $\eta = m$
$E_s$	skewed chord extension (See fig. 1(a).)
$F_{l,m}$	fences at $\eta = l$ and $\eta = m$ on the wing placed parallel to model plane of symmetry
LE	modified leading-edge radius
$LF_\eta$	Krueger type leading-edge flap with outboard end at $\eta$
$LS_{l \rightarrow m}$	spoiler on wing leading edge in wing chord plane with inboard and outboard ends at $\eta = l$ and $m$ , respectively
N	nose portion of fence
RR	wing with rounded-root plan form
T	rear portion of fence

## MODELS

The basic models used in this investigation are identical to the models used in the tests reported in references 1 and 2. The models with aspect ratio 2 and 3 wings will be referred to hereinafter as models A2 and A3, respectively. Drawings of the models are shown in figure 2 and pertinent geometric data are presented in table I.

Airfoil sections of the wings parallel to the model plane of symmetry were NACA 0005 sections modified with a straight line fairing from the 67-percent station to the wing trailing edge. The wings were equipped with partial-span single-slotted flaps.

The horizontal tails were installed at  $0^\circ$  incidence (with respect to the wing chord plane) on the vertical tail at 0.25 and 0.21 semispan above the wing chord plane for models A2 and A3, respectively.

Details of the wing modifications investigated are presented in figure 3. The spanwise locations of the various wing modifications were set within an accuracy of  $0.003b/2$ . Hereinafter each wing modification will be referred to by the notation indicated in figure 3 and defined in the section Notation. As indicated by figure 3(b), all fence lengths included in wing modifications for model A3 are those of N, C, T when  $\delta_f = 0^\circ$  and N, C when  $\delta_f = 40^\circ$ . For model A2, the fence lengths used on each wing modification for which results of tests are presented herein are listed in table II.

## TESTS

The major part of the investigation consisted of tests of the various wing modifications on the models with the horizontal tail installed and with the flaps undeflected. A few of the modifications were tested on the models with the horizontal tail off and flaps undeflected, and with the horizontal tail on and flaps deflected.

For all model configurations, force and moment data were obtained at  $0^\circ$  sideslip through an angle-of-attack range of from  $-2^\circ$  to  $24^\circ$ . The Reynolds numbers of the tests were 14.6 and 12.8 million for models A2 and A3, respectively. The dynamic pressure was approximately 25 pounds per square foot and the Mach number was 0.13 for both models.

## RESULTS AND DISCUSSION

Although all the wing modifications shown in figure 1 were investigated, the results presented herein are limited to those which indicate the general effectiveness of each type of wing modification tested. Table III is an index to the basic aerodynamic data presented in figures 4 through 9. All pitching-moment data presented in figures 4, 5, 6, and 9 are referred to a moment center located at the quarter-chord station of the mean aerodynamic chord. The data were corrected for wind-tunnel effects and support-strut interference.

Typical variations of  $dC_m/dC_L$  with  $C_L$  for various types of wing modifications are presented in figure 10, for models with tail off and on. Since the stability changes due to wing modification were slight with the tail off as compared to those with the tail on, the effects of wing modification for the models with the tail on may be attributed to changes in the pitching-moment contribution of the horizontal tail.

From figures 4 and 10 it may be seen that with the tail on, the most effective of the wing modifications tested did not completely eliminate the reduced stability shown by the basic models at high lift coefficients. However, for the lift range from approximately  $C_L = 0$  to  $C_L = 0.9$ , the destabilizing changes in  $dC_m/dC_L$  of 0.23 and 0.20 for the basic models A2 and A3, respectively, were decreased to approximately 0.10 for both models by the most effective chord-extension fence combinations. These improvements in stability are also demonstrated in figure 11 in which are presented tail-on pitching-moment characteristics based on moment centers which produce a static margin of 0.06c (at  $C_L = 0$ ).

Ames Aeronautical Laboratory  
National Advisory Committee for Aeronautics  
Moffett Field, Calif., Feb. 9, 1954

## REFERENCES

1. Graham, David, and Koenig, David G.: Tests in the Ames 40- by 80-Foot Wind Tunnel of an Airplane Configuration With an Aspect Ratio 2 Triangular Wing and an All-Movable Horizontal Tail - Longitudinal Characteristics. NACA RM A51B21, 1951.
2. Koenig, David G.: Tests in the Ames 40- by 80-Foot Wind Tunnel of an Airplane Configuration With an Aspect Ratio 3 Triangular Wing and an All-Movable Horizontal Tail - Longitudinal and Lateral Characteristics. NACA RM A52L15, 1953.

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TABLE I.- GEOMETRIC DATA

Wing	Model A2	Model A3
Area, sq ft . . . . .	312.50	313.76
Span, ft . . . . .	25.00	30.64
Mean aerodynamic chord, ft . . . . .	16.67	13.65
Aspect ratio . . . . .	2.00	2.99
Taper ratio . . . . .	0	0
Airfoil section parallel to model center line . . . . .	NACA 0005 (modified)	NACA 0005 (modified)
Fuselage		
Length, ft . . . . .	56.16	56.16
Maximum diameter, ft . . . . .	4.49	4.49
Fineness ratio . . . . .	12.50	12.50
Vertical tail		
Exposed area, sq ft . . . . .	52.53	52.53
Aspect ratio of plan form, extended to model center line . . . . .	1	1
Taper ratio . . . . .	0	0
Airfoil section parallel to model center line . . . . .	NACA 0005 (modified)	NACA 0005 (modified)
Slotted, trailing-edge flaps		
Chord . . . . .	0.2084c	1.96 ft
$S_f/S$ (total movable) . . . . .	0.200	0.119
$b_f/b$ (total movable) . . . . .	0.528	0.622
Horizontal tail		
$S_t/S$ . . . . .	0.200	0.199
$b_t/b$ . . . . .	0.632	0.516
$l_t/\bar{c}$ (for moment center at $0.25\bar{c}$ ) . . . . .	1.337	1.735
Aspect ratio . . . . .	4.0	4.0
Taper ratio . . . . .	0.50	0.50
$z/(b/2)$ . . . . .	0.25	0.21

TABLE II.- MODEL A2 - FENCE LENGTHS USED  
FOR VARIOUS WING MODIFICATIONS

Fence lengths	Wing modification	Horizontal tail	$\delta f$
N, C	F30; F40; F50; F30,50	On and off	00
↓	F30,50	On	4000
↓	E50→100, F40	Off	00
N, C, T	E50→100, F30	On	4000
↓	E50→100, F40	On	00
↓	E50→100, F50	On	00
C, T	E40→100, F30	On	00
↓	E50→100, F30	On	00
C, T	E40→100, F40	On	00

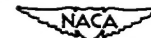




TABLE III.- INDEX TO BASIC AERODYNAMIC DATA

Figure	Model	Flap deflection, deg	Horizontal tail	Wing modification
Pitching-moment characteristics				
4(a,b)	A2	0	On	Basic; E <sub>40</sub> →100; E <sub>50</sub> →100; E <sub>8</sub> ; F <sub>30</sub> ; F <sub>40</sub> ; F <sub>50</sub> ; F <sub>30,50</sub> ; E <sub>50</sub> →100, F <sub>30</sub> ; E <sub>50</sub> →100, F <sub>40</sub> ; E <sub>50</sub> →100, F <sub>50</sub> ; E <sub>40</sub> →100, F <sub>30</sub> ; E <sub>40</sub> →100, F <sub>40</sub> ; RR; RR, LS <sub>60</sub> →90
4(c)	A3	0	On	Basic; E <sub>40</sub> →48; E <sub>40</sub> →80; F <sub>24</sub> ; F <sub>32</sub> ; F <sub>24,32</sub> ; E <sub>40</sub> →48, F <sub>24</sub> ; E <sub>40</sub> →48, F <sub>32</sub> ; E <sub>40</sub> →80, F <sub>24</sub> ; E <sub>40</sub> →80, F <sub>32</sub> ; LF <sub>48</sub> ; LE
5(a)	A2	0	Off	Basic; E <sub>8</sub> ; E <sub>50</sub> →100; F <sub>40</sub> ; F <sub>30,50</sub> ; E <sub>50</sub> →100, F <sub>40</sub> ; RR; RR, LS <sub>80</sub> →90
5(b)	A3	0	Off	Basic; E <sub>40</sub> →80; F <sub>24,32</sub> ; E <sub>40</sub> →80, F <sub>32</sub> ; LF <sub>48</sub> ; LE
6	A2 and A3	40	On	Basic; F <sub>30,50</sub> ; E <sub>50</sub> →100, F <sub>30</sub> ; RR, LS <sub>60</sub> →90, F <sub>24,32</sub> ; E <sub>40,80</sub> , F <sub>32</sub> ; LF <sub>48</sub>
Lift characteristics				
7(a)	A2	0	Off and on	Basic; E <sub>50</sub> →100; F <sub>30,50</sub> ; E <sub>50</sub> →100, F <sub>40</sub> ; RR; RR, LS <sub>80</sub> →90
7(b)	A3	0	Off and on	Basic; E <sub>40</sub> →80; F <sub>24,32</sub> ; E <sub>40</sub> →80, F <sub>32</sub> ; LF <sub>48</sub> ; LE
Drag characteristics				
8(a)	A2	0	Off and on	Basic; E <sub>50</sub> →100; F <sub>30,50</sub> ; E <sub>50</sub> →100, F <sub>40</sub> ; RR, RR, LS <sub>80</sub> →90
8(b)	A3	0	Off and on	Basic; E <sub>40</sub> →80; F <sub>24,32</sub> ; E <sub>40</sub> →80, F <sub>32</sub> ; LF <sub>48</sub> ; LE
9	A2	0	On	E <sub>40</sub> →100, F <sub>30</sub> ; E <sub>50</sub> →100, F <sub>40</sub> ; F <sub>30,50</sub>



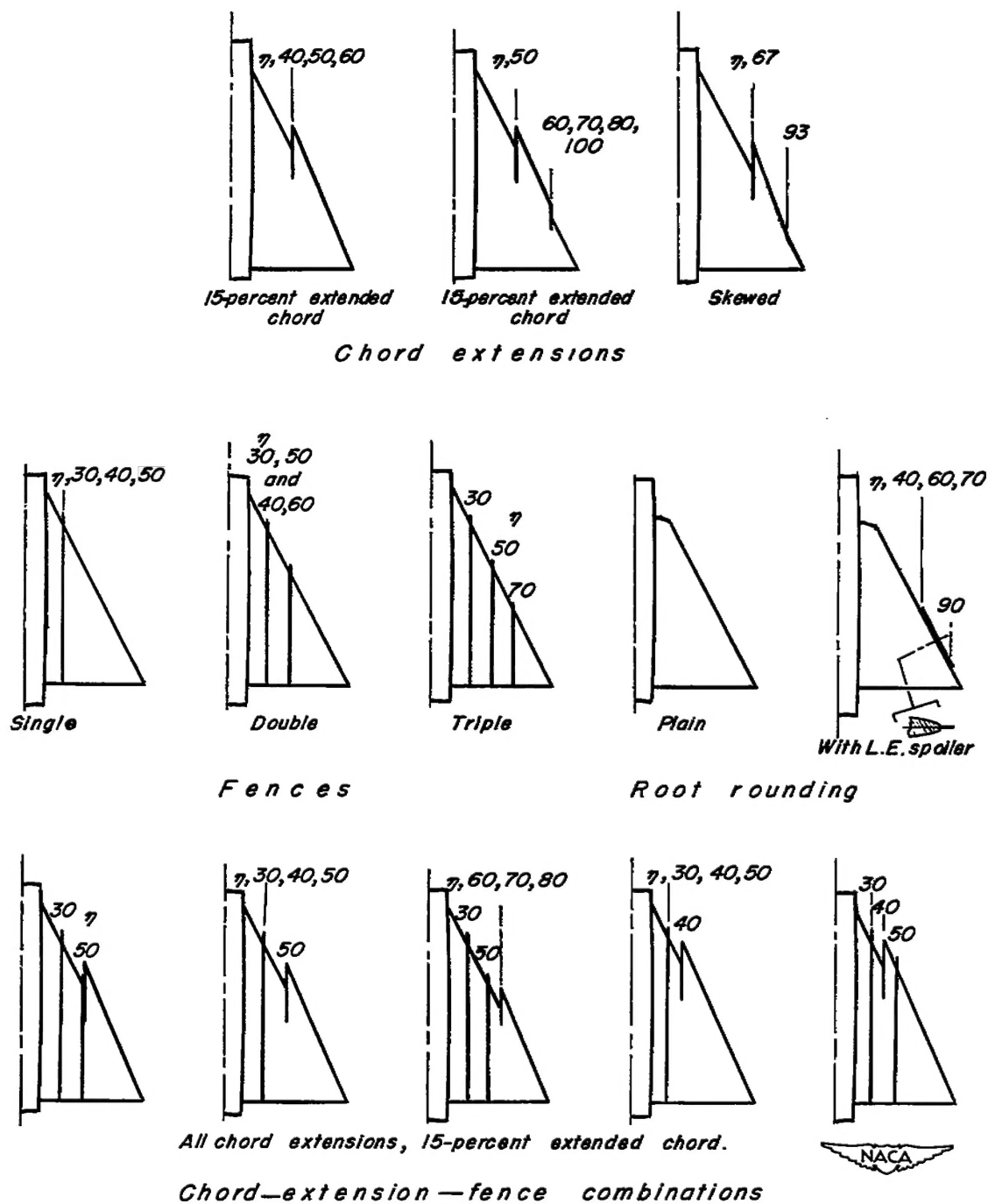
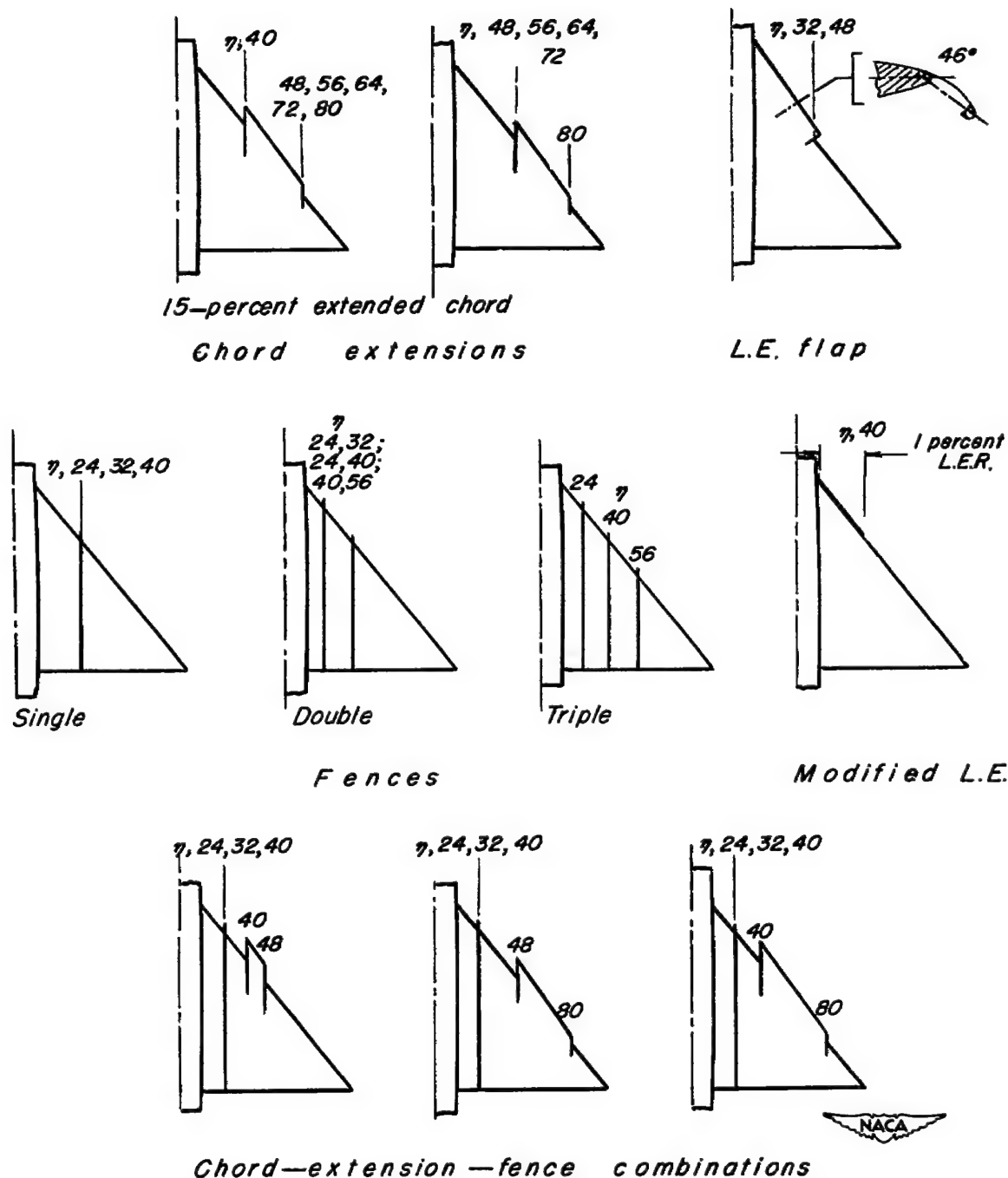


Figure 1.- The wing modifications investigated.



(b) Model with aspect ratio 3 wing.

Figure 1.- Concluded.

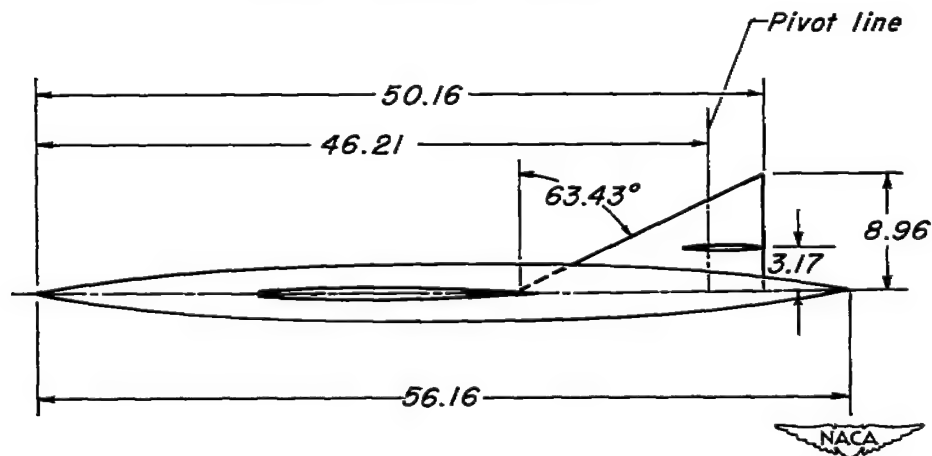
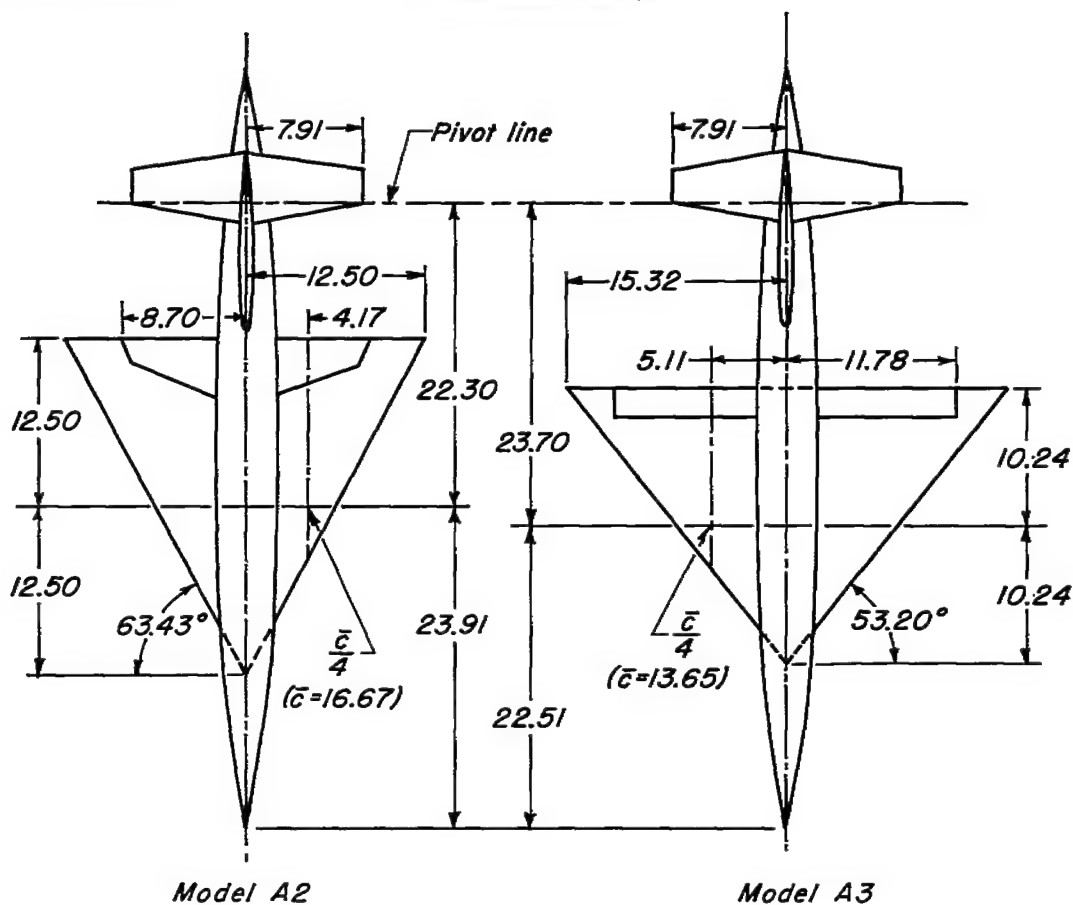
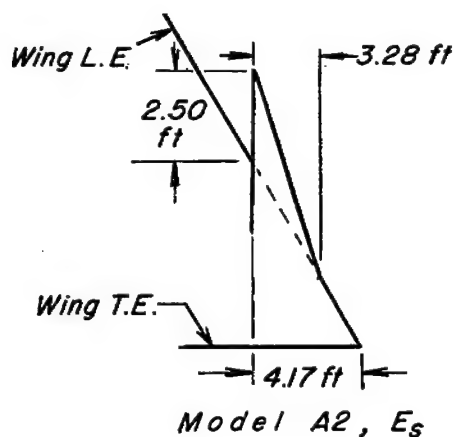
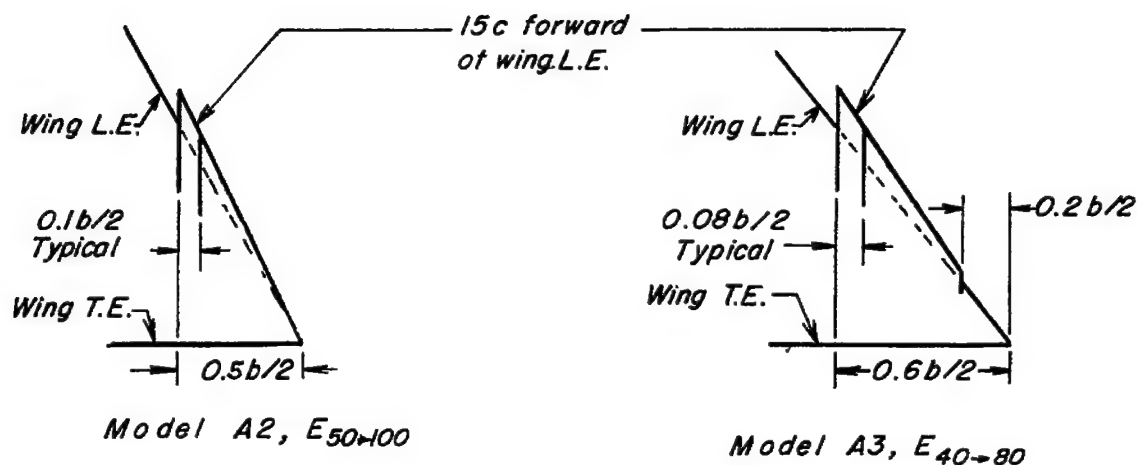
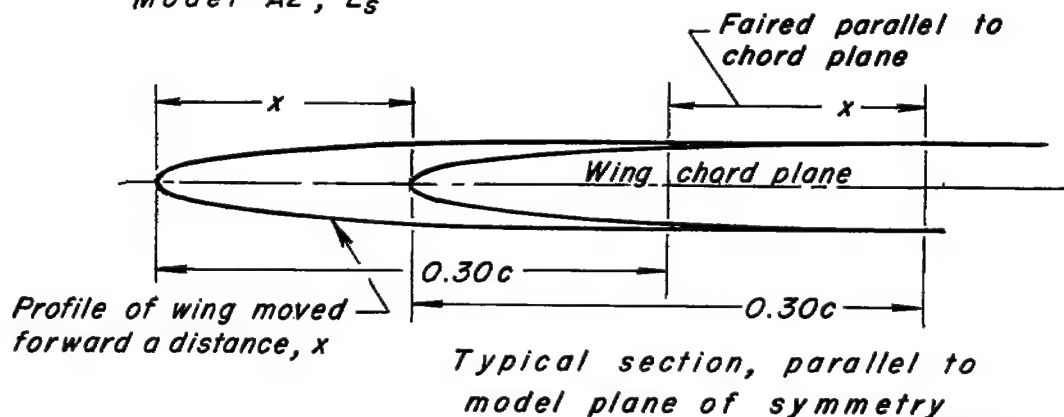


Figure 2.- Geometric details of the basic models.

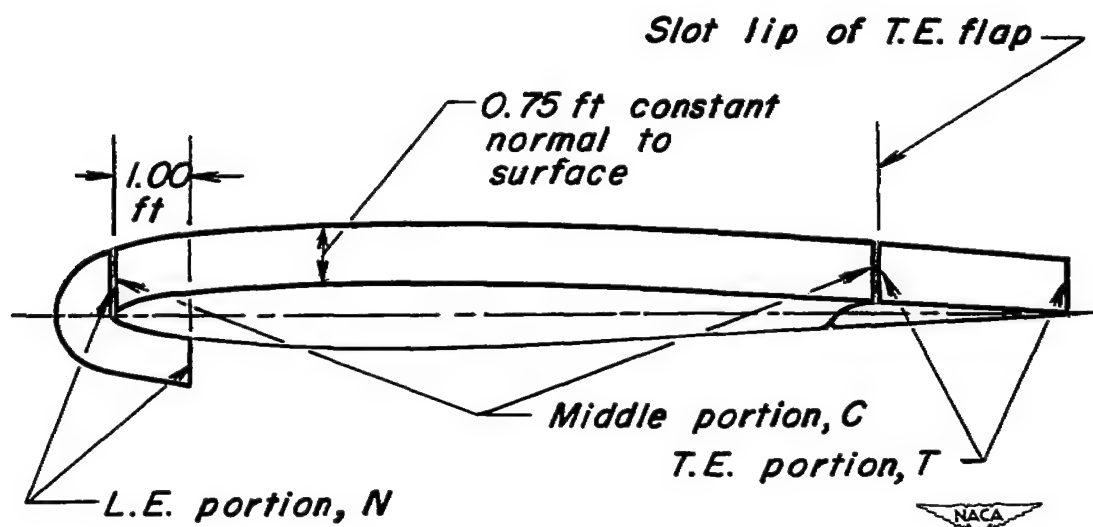


Note: Except for  $E_s$ , chord extensions are designated as  $E_{t-m}$ , with the inboard end at  $\eta=1$  and the outboard end at  $\eta=m$ .



(a) Chord extensions.

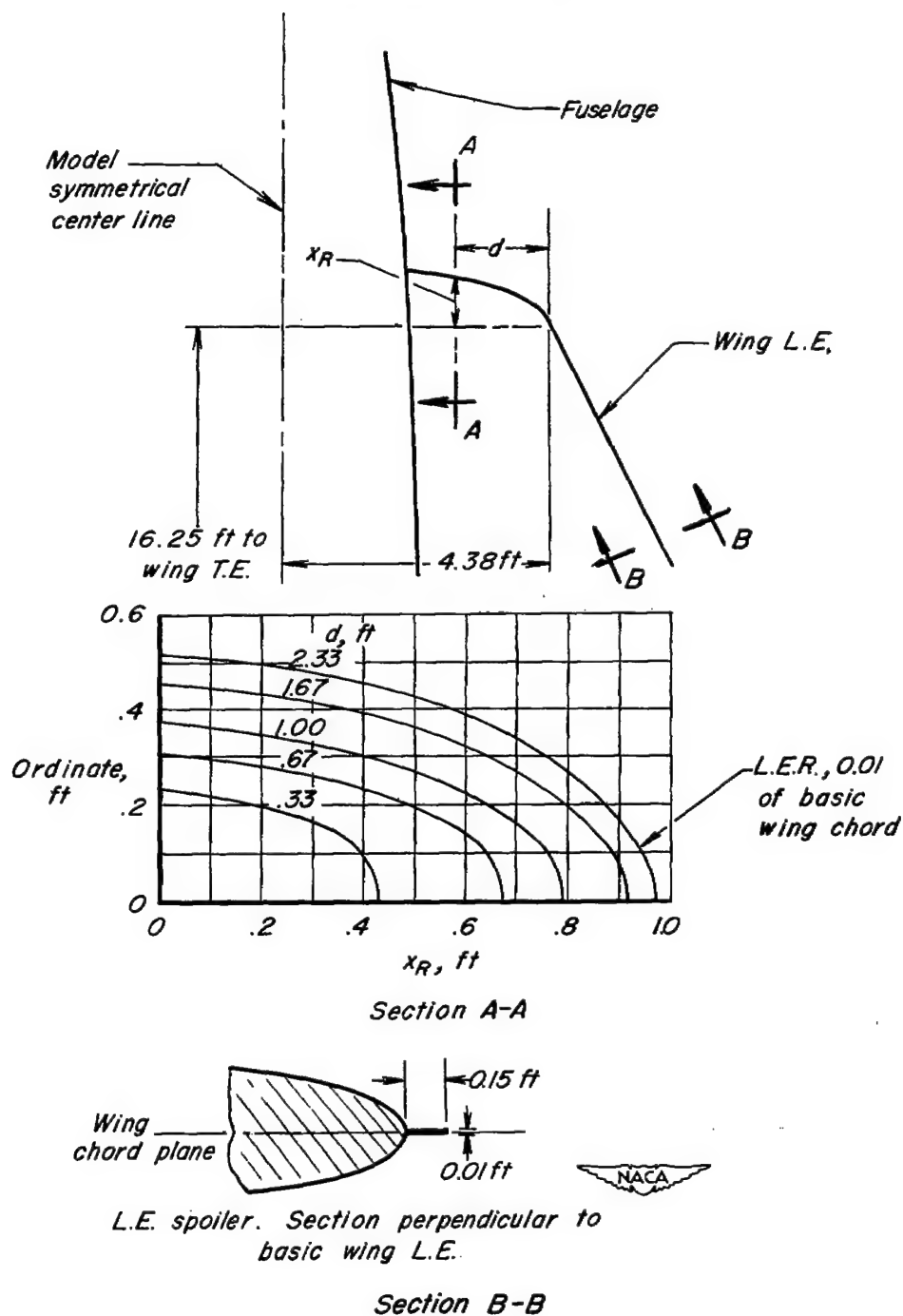
Figure 3.- Details of wing modifications investigated.



*Note: For model A2, N or T were removed for some configurations.  
For model A3, all fence configurations with  $\delta_f = 0^\circ$  included N, C, and T.  
For both models,  $\delta_f = 40^\circ$ , T was removed.  
For both models,  $F_l$  or  $F_{l,m}$  indicates fences at  $\eta = l$  or  $\eta = l$  and  $m$ .*

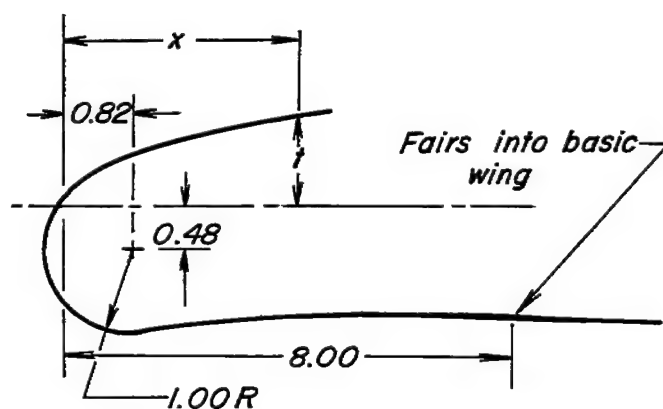
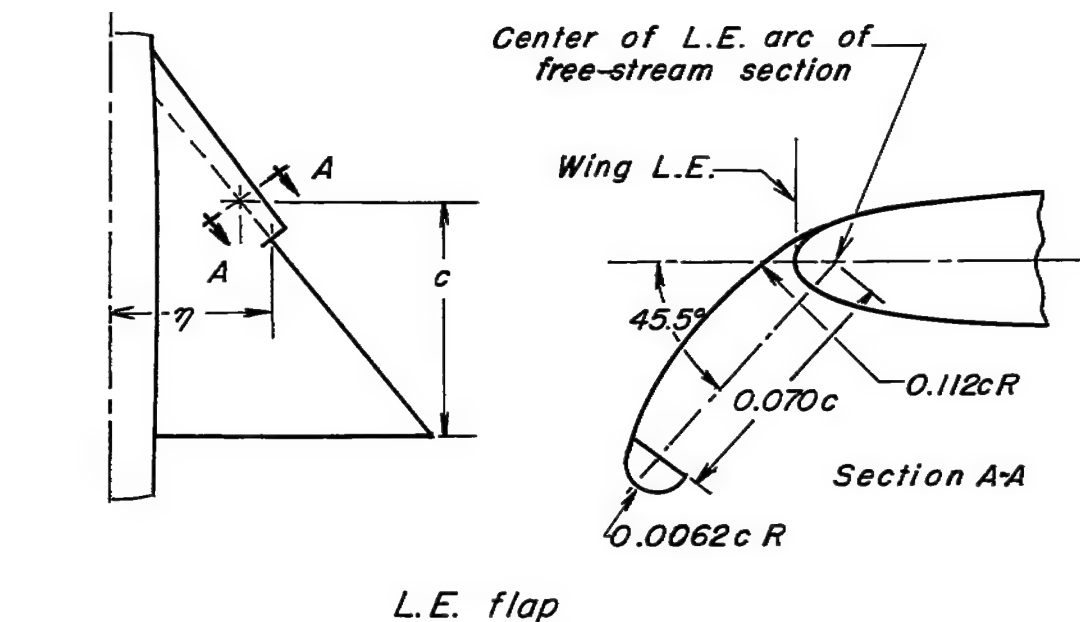
(b) Fences.

Figure 3.- Continued.



(c) Root rounding and spoiler details for model A2.

Figure 3.- Continued.



This section is typical for wing sections parallel to model plane of symmetry from fuselage to  $\eta=40$ . From  $\eta=40$  to  $\eta=50$ , L.E. radius reduces to that of basic wing section.

$x$	$t$	
	Upper	Lower
-0.18	-0.49	-0.49
0	.11	-1.06
0.75	.60	-1.48
1.00	Basic wing	-1.48
2.00		-1.45
4.00		-1.49
6.00		-1.64
8.00		-1.80

Dimensions shown in percent chord

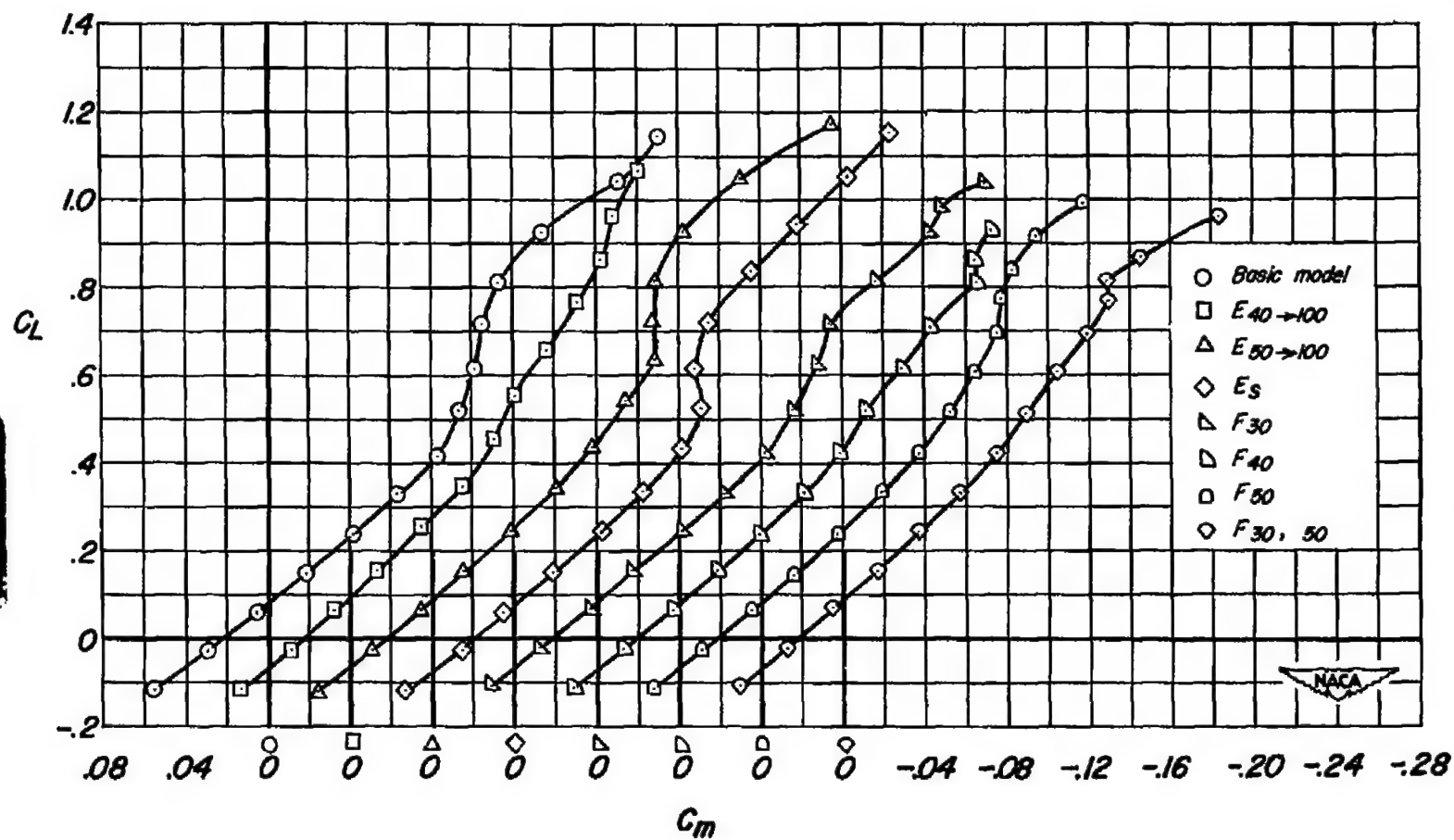


### Modified L.E.

(d) Details of leading-edge flap and modified wing leading edge for model A3.

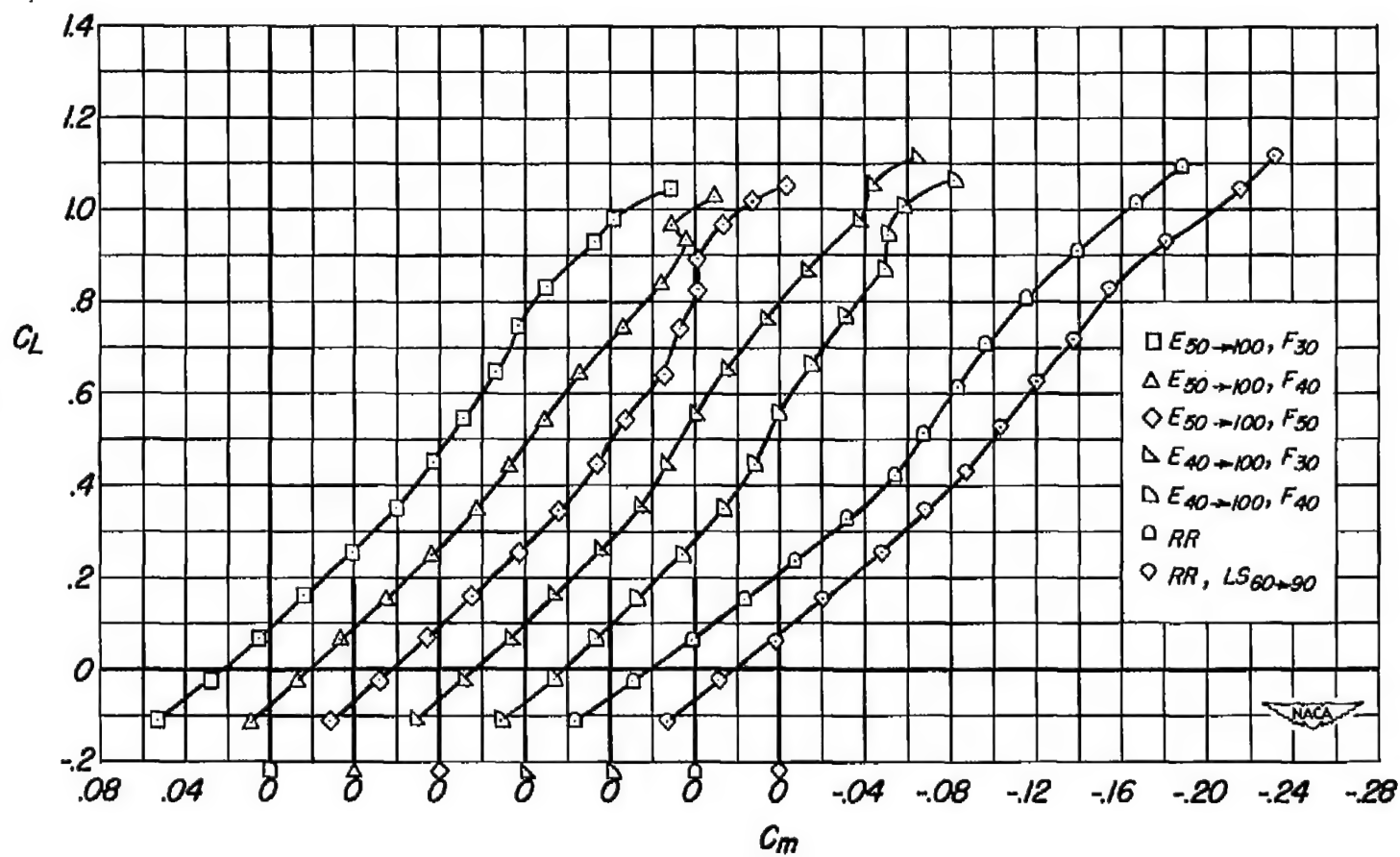
Figure 3.- Concluded.





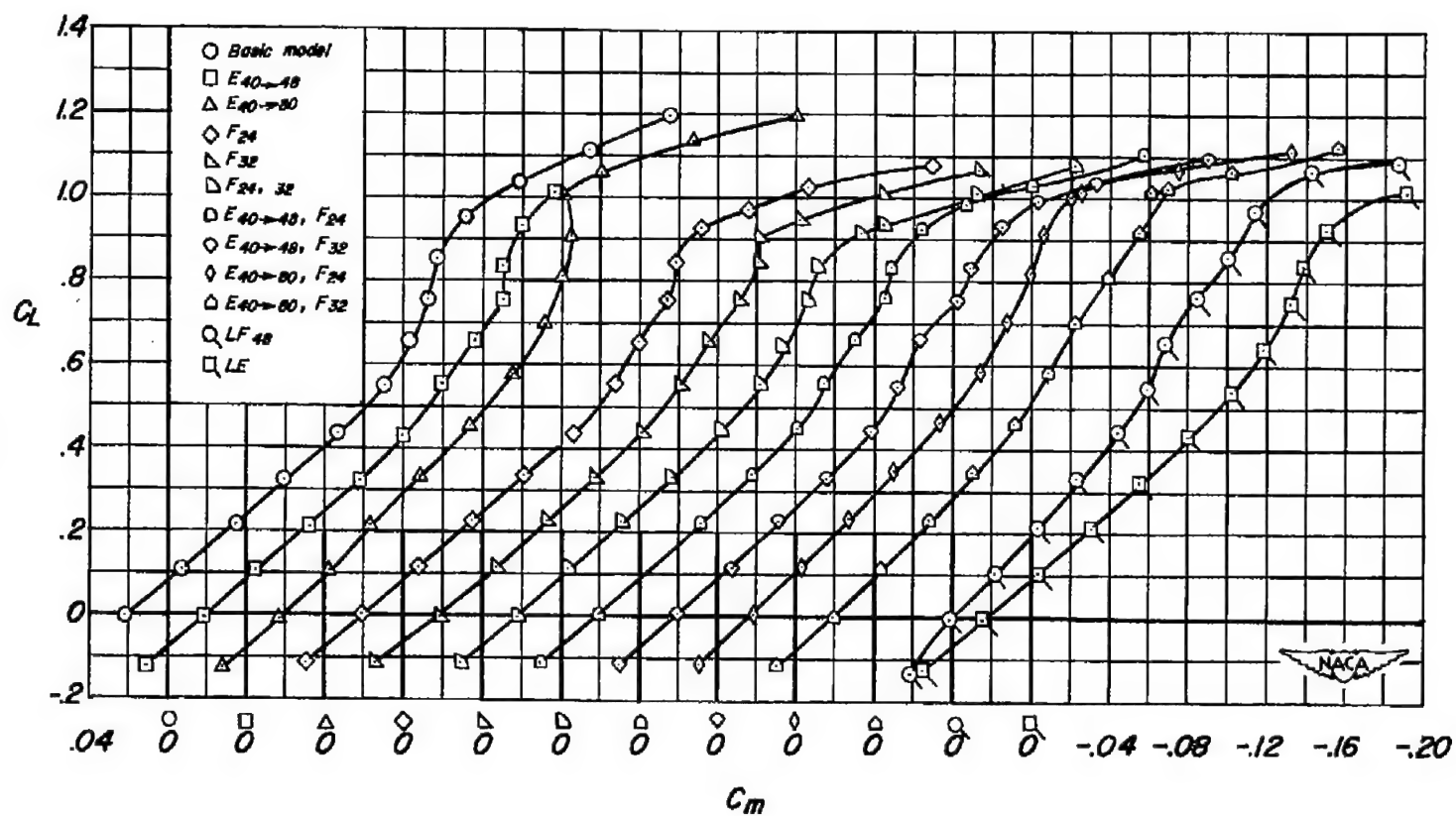
(a) Model A2; wing modifications, E and F.

Figure 4.- Pitching-moment characteristics of the models with the flaps undeflected; horizontal tail on.



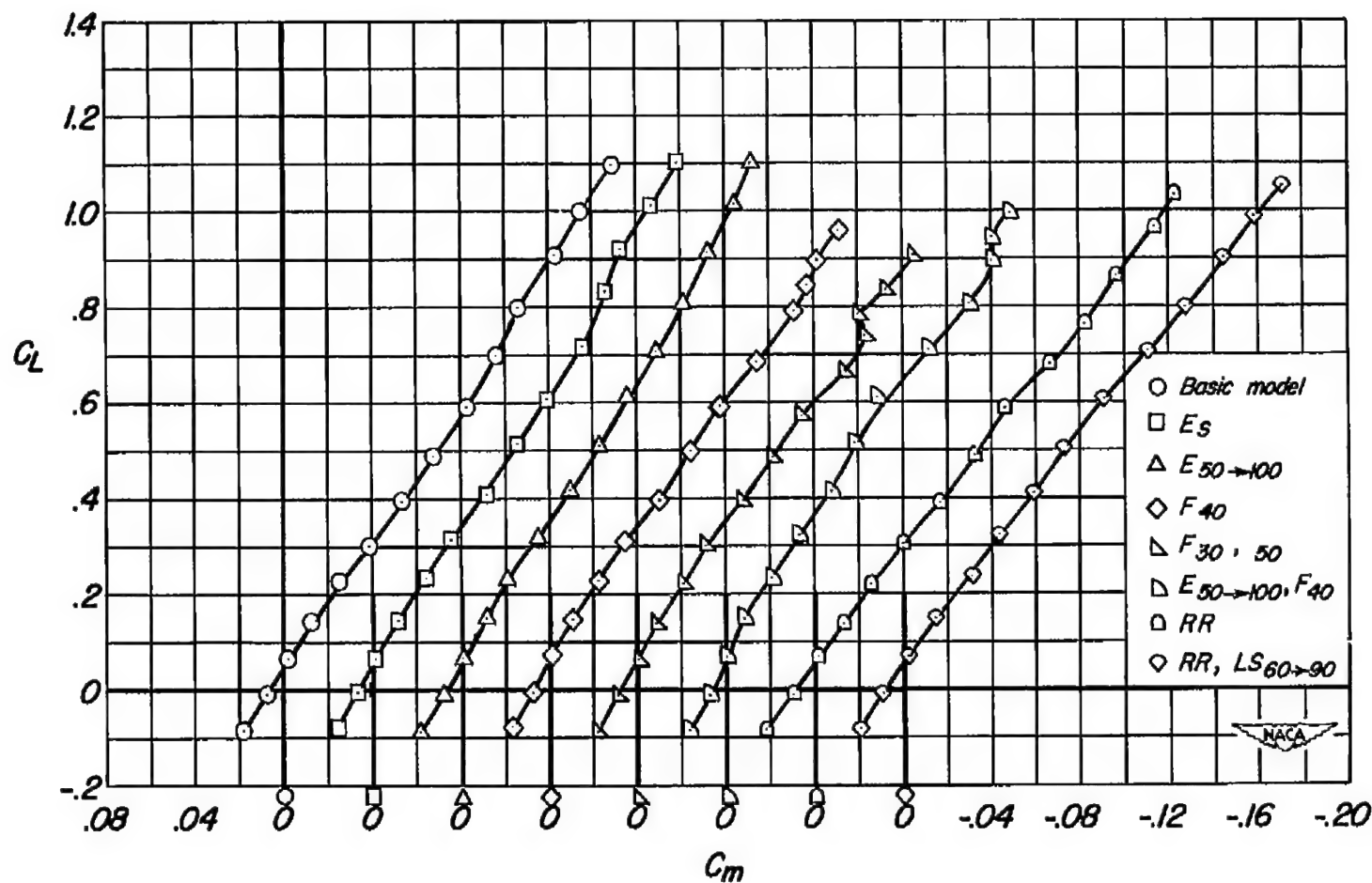
(b) Model A2; wing modifications, E, F, and RR.

Figure 4.- Continued.



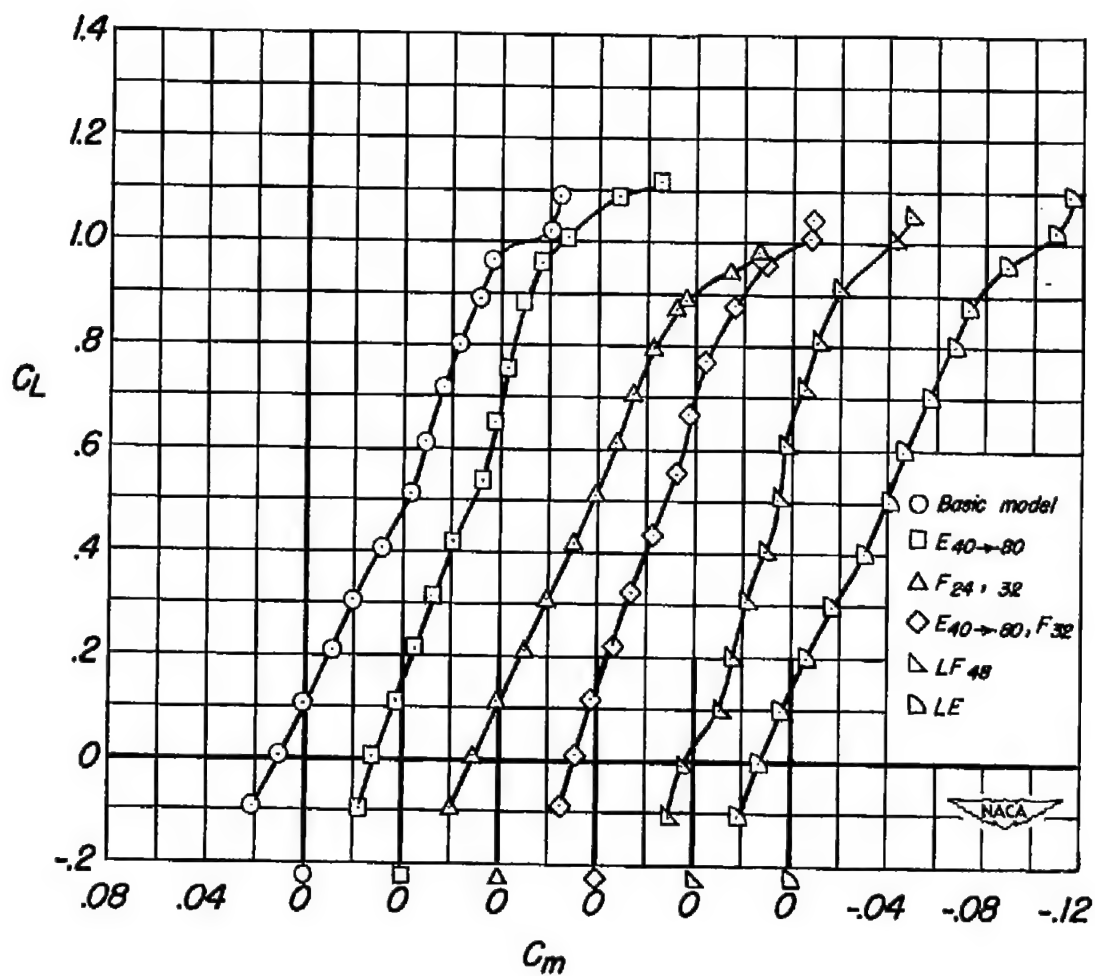
(c) Model A3; all wing modifications.

Figure 4.- Concluded.



(a) Model A2.

Figure 5.- Pitching-moment characteristics of the models with the flaps undeflected; horizontal tail off.



(b) Model A3.

Figure 5.- Concluded.

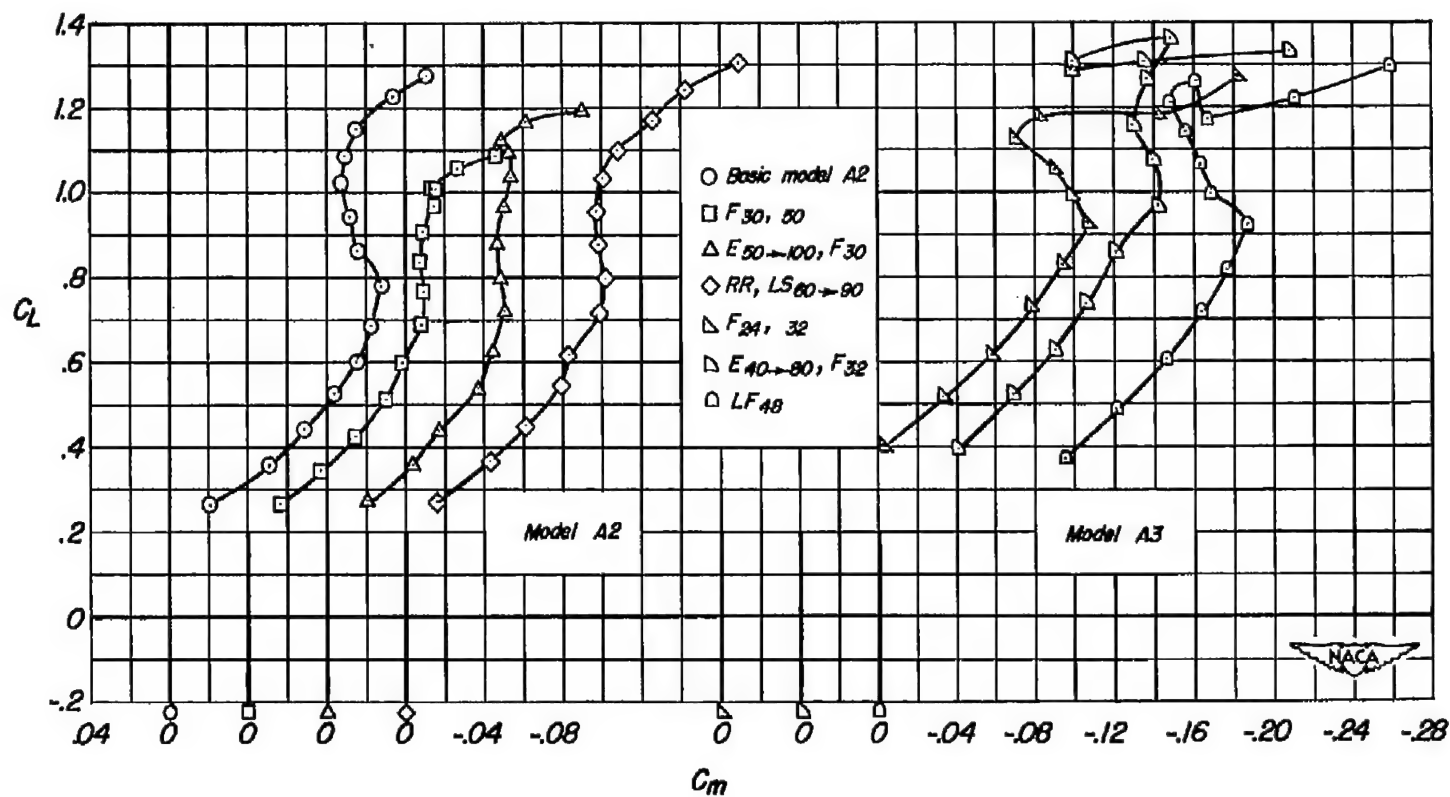
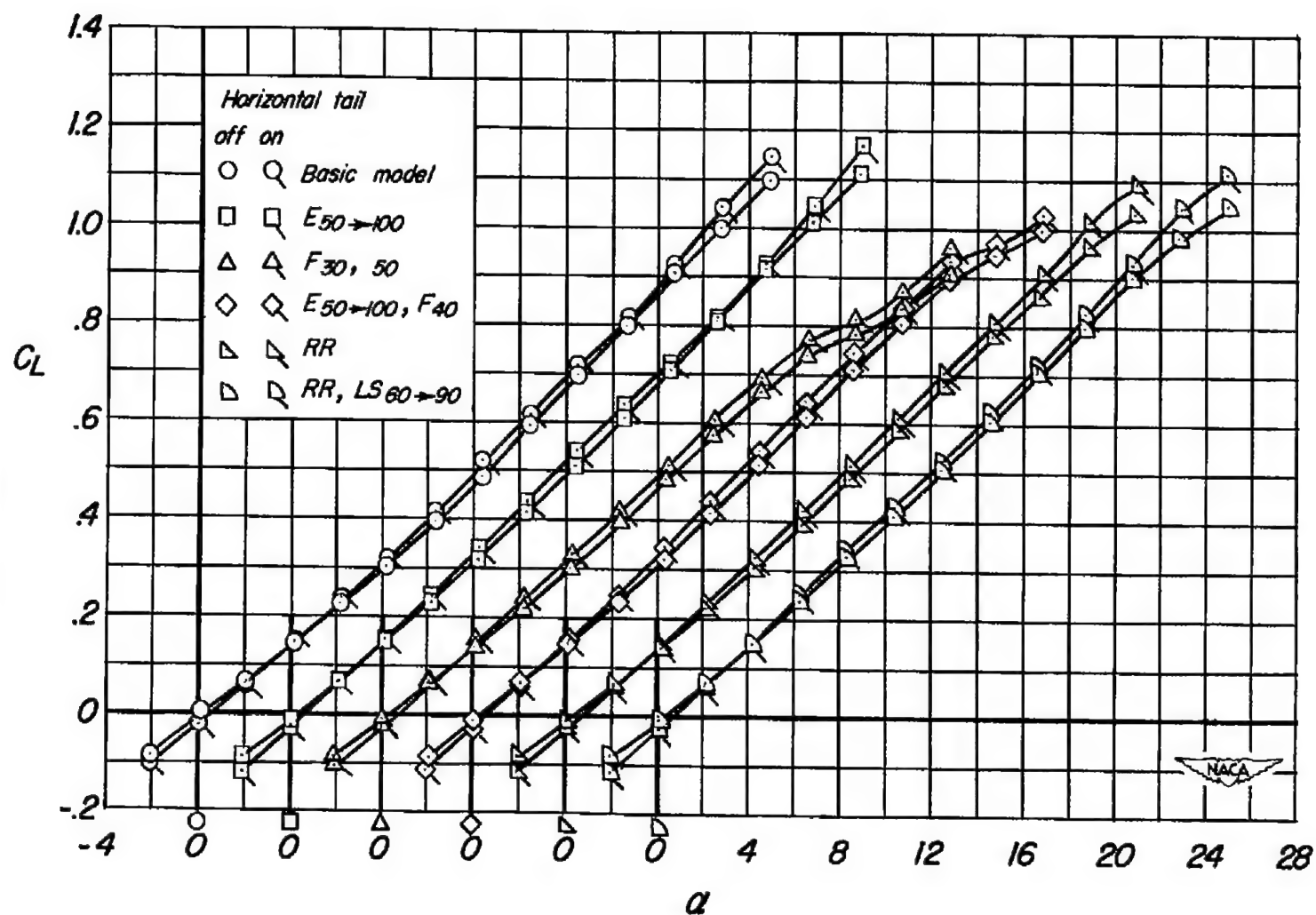
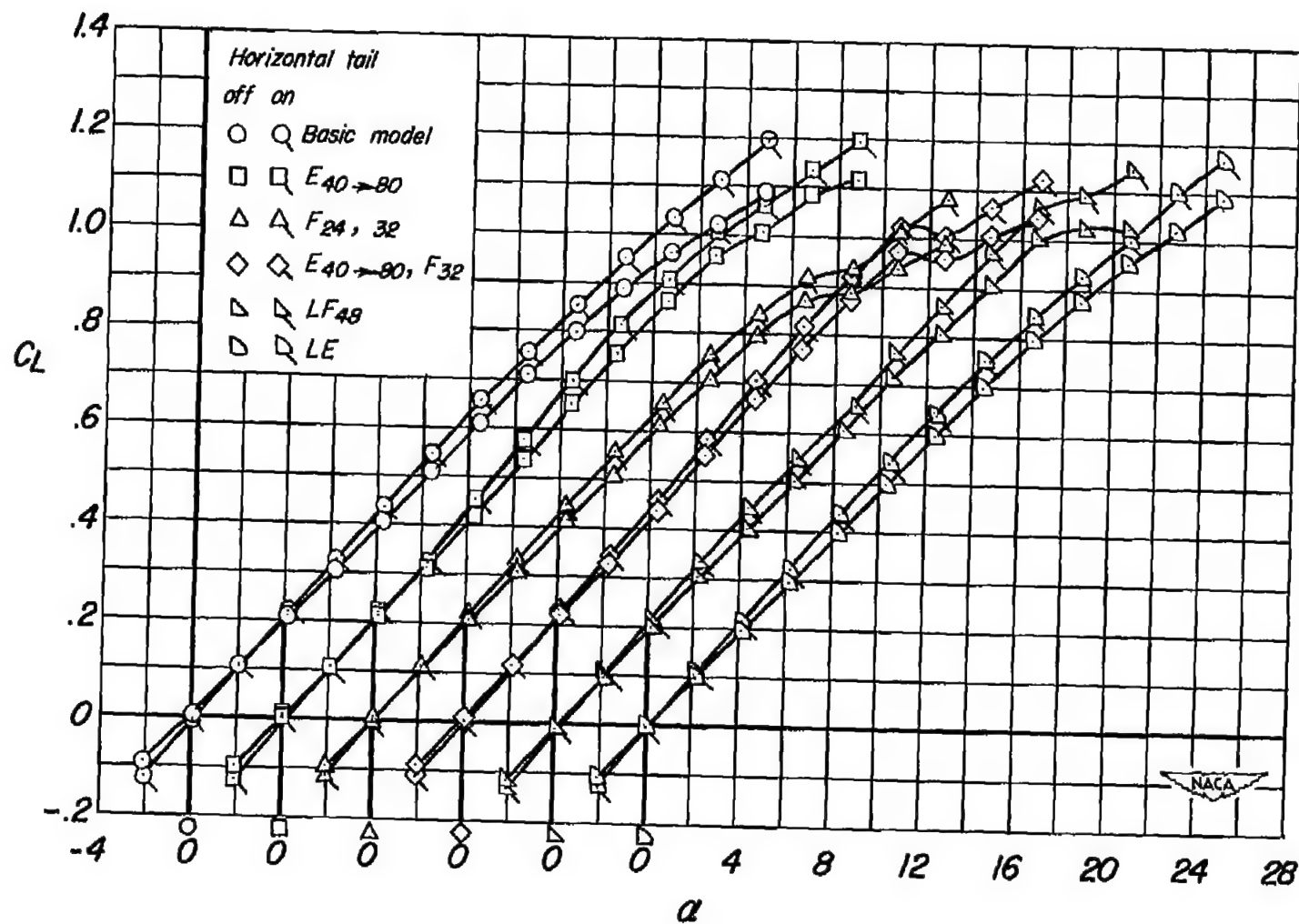


Figure 6.- Pitching-moment characteristics of the models with flaps deflected  $40^\circ$ ; horizontal tail on.



(a) Model A2.

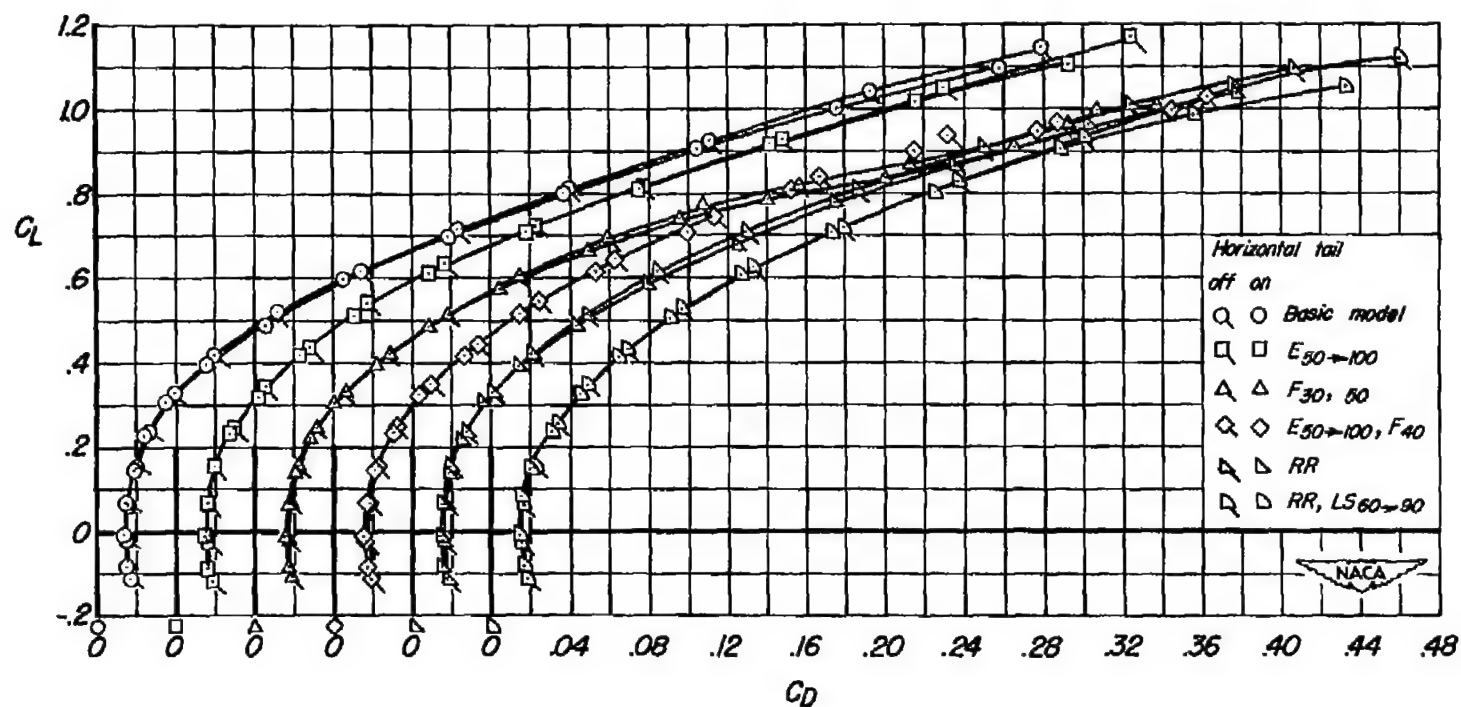
Figure 7.- Lift characteristics of the models with the flaps undeflected.



(b) Model A3.

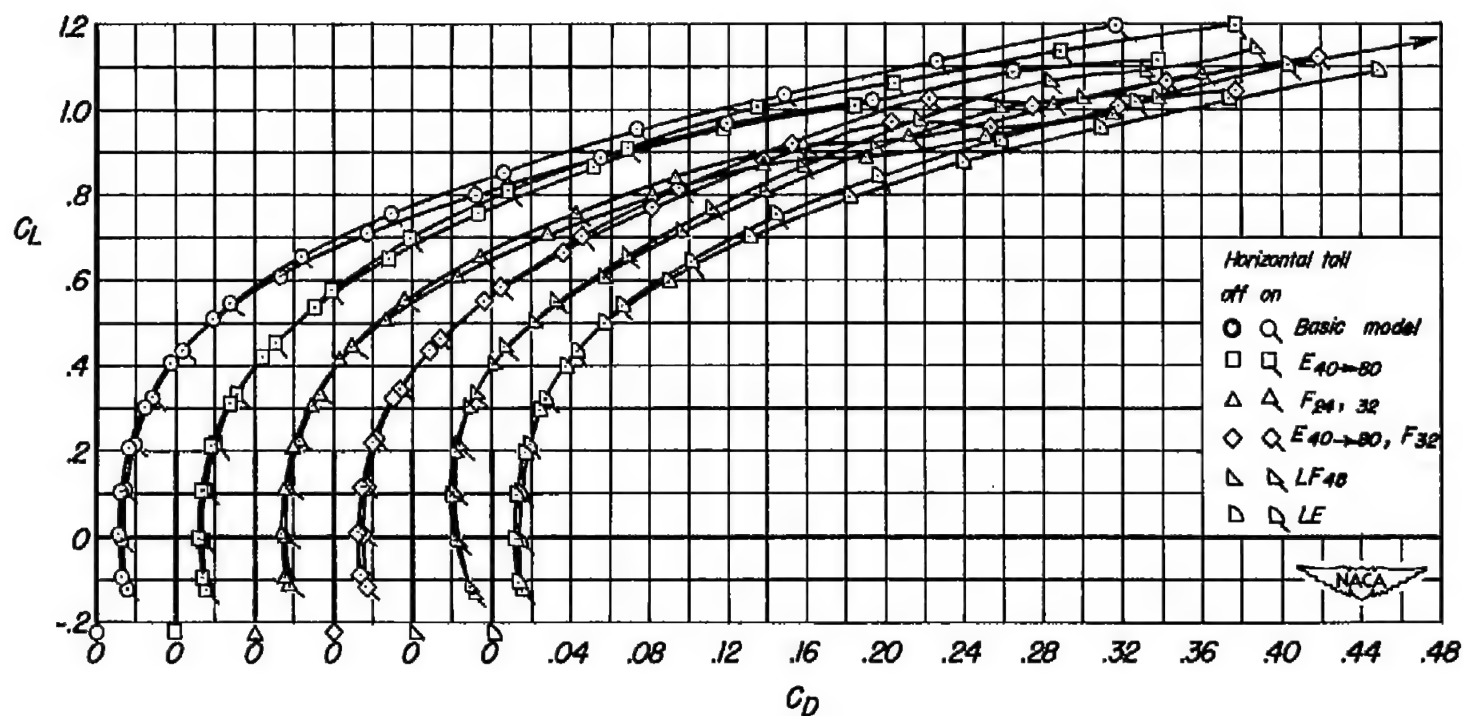
Figure 7.- Concluded.





(a) Model A2.

Figure 8.- Drag characteristics of the models with the flaps undeflected.



(b) Model A3.

Figure 8.- Concluded.

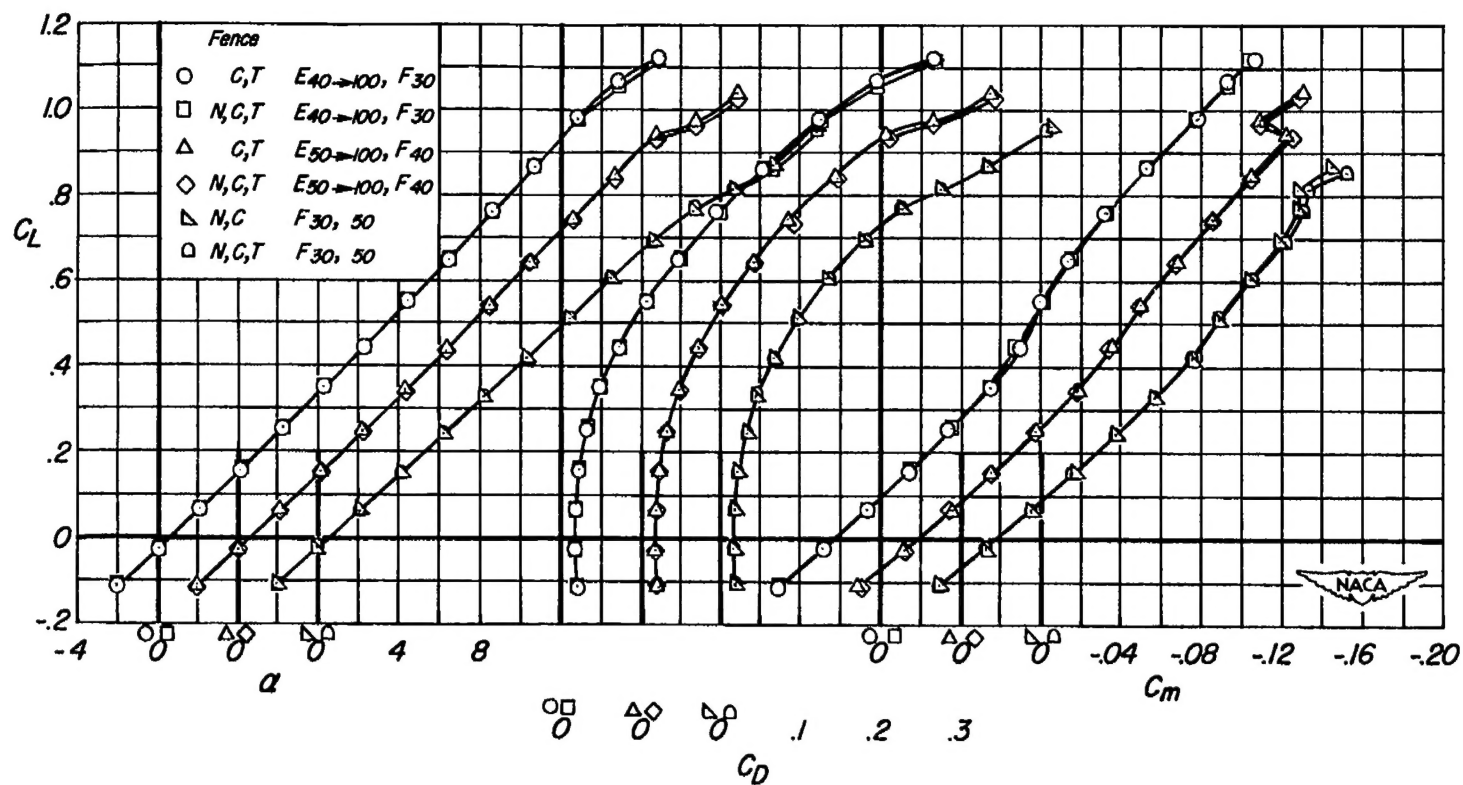
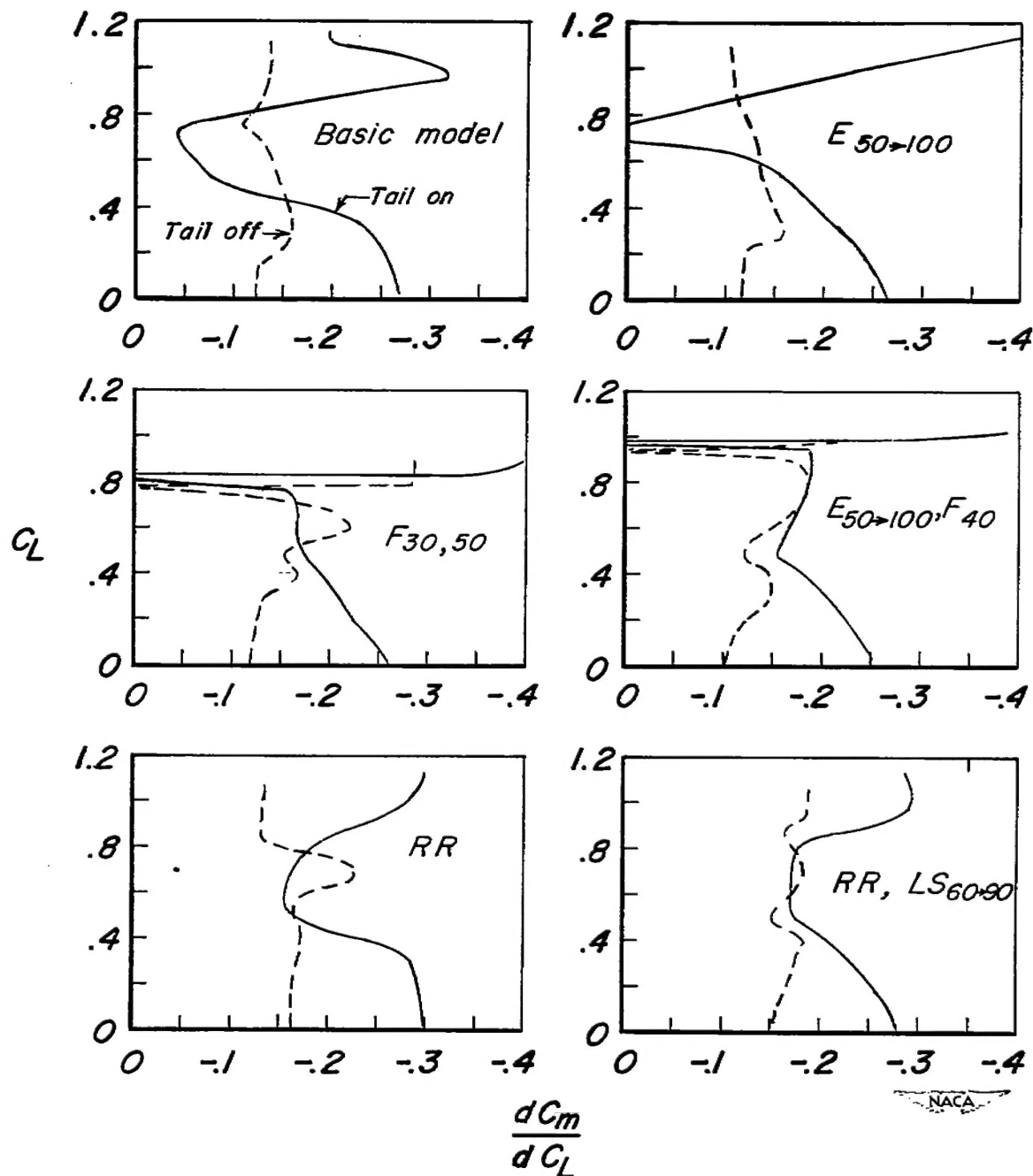
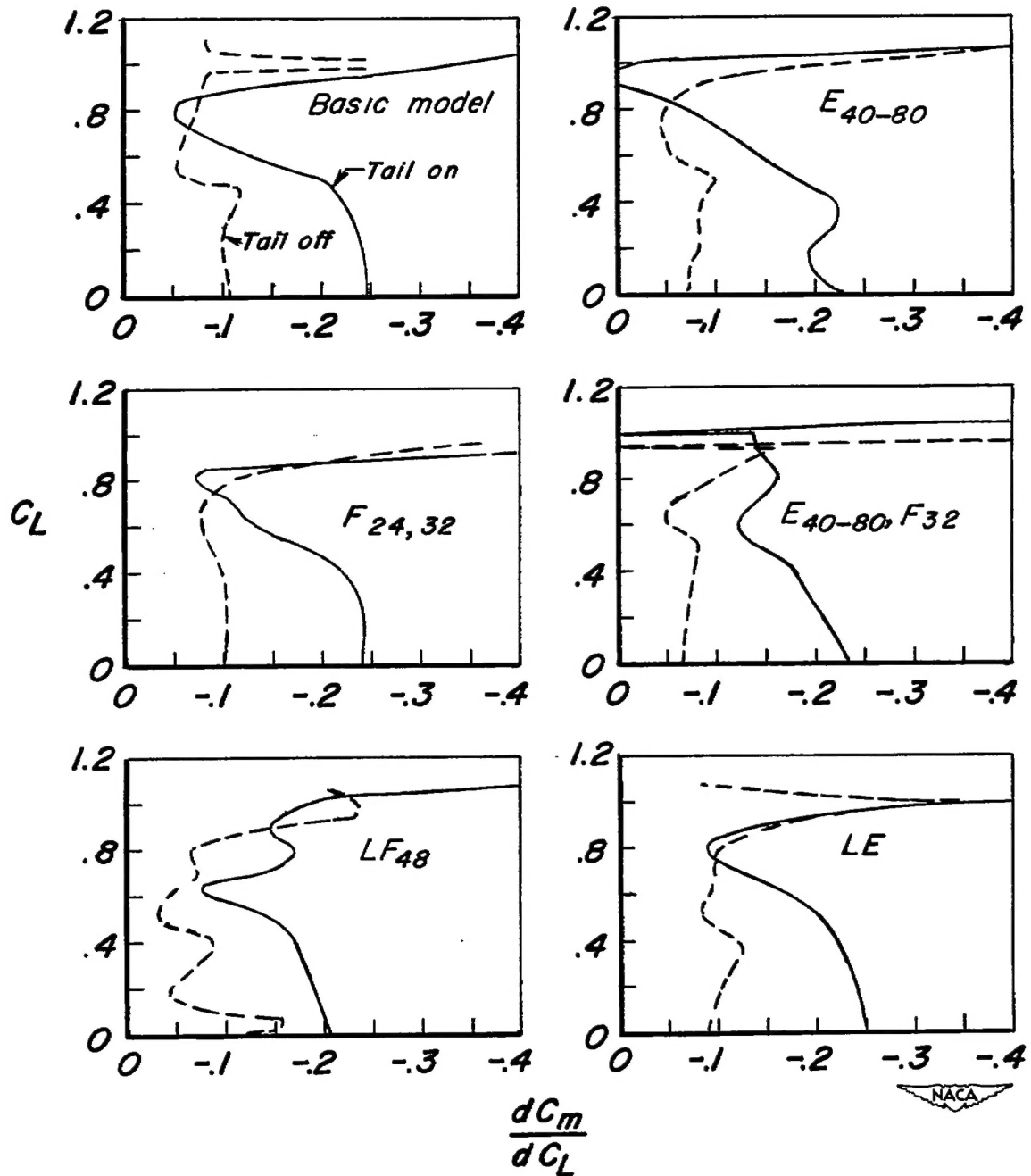


Figure 9.- Effect of fence length on the characteristics of model A2 with horizontal tail on;  $\delta_F = 0^\circ$ .



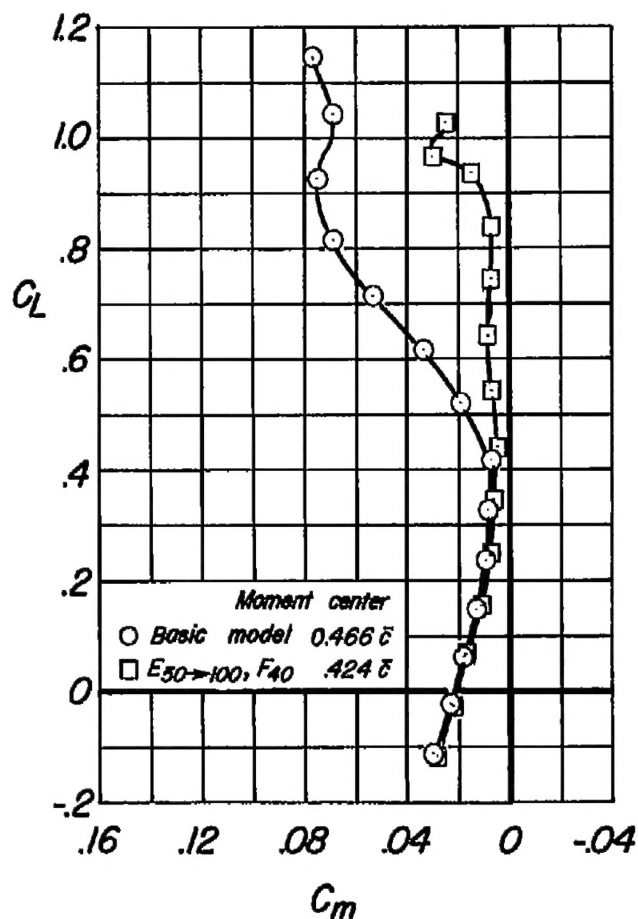
(a) Model A2.

Figure 10.- The variation of  $\frac{dC_m}{dC_L}$  with lift coefficient for various wing modifications.

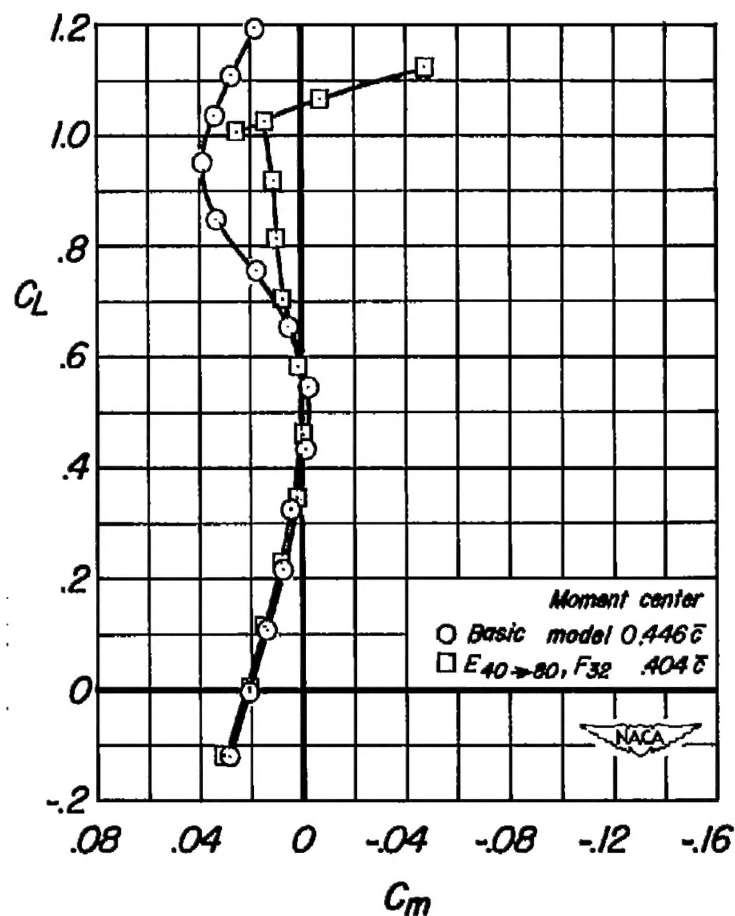


(b) Model A3.

Figure 10.- Concluded.



(a) Model A2.



(b) Model A3.

Figure 11.- Effect on the pitching-moment characteristics of the models of a chord extension in combination with a fence;  $dC_m/dC_L(C_L=0) = -0.06\bar{c}$ ; horizontal tail on.